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ULTRASTRUCTURE OF THE ROOT CAP OF ARABIDOPSIS THALIANA L. HEYNH UNDER SPACEFLIGHT CONDITIONS

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16. Abstract

The paper deals with peculiarities of the ultrastructural organization of Arabidopsis root cap cells grown from the stage of two cotyledonous leaves in the "Svetoblok-1" apparatus aboard the Salyut 6 research orbital station and in the laboratory. It is established that under conditions of real space flight vacuolization of the root cap cells increases considerably compared to the control variant. Changes in the topography and ultrastructure of amyloplasts as well as lysis of cell walls are observed in the material under study. An assumption is advanced on analogous cell responses observed at the ultrastructural level to weightlessness and clinostatic conditions.

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The accomplishment of the basic processes of growth and development of higher plants in weightlessness, at least in the vegetative phase of ontogenesis, makes it possible to study the structural and functional organization of the evolutionary development of the gravity receptor (the root cap) in the absence of a gravitational stimulus. Electron microscope analysis was carried out of the cells of the root cap of Arabidopsis plants which were grown aboard the Salyut-6 orbital research station in the Svetoblok-1 apparatus. The latter protects the growth of small higher plants in an agarized nutrient medium under sterile airtight conditions with 2000-4000 lux illumination. Aboard the station, the apparatus was provided with two cotyledonous leaf phase seedlings.[1] After completion of 2 studies, which lasted 60 and 65 days, the plants grown in weightlessness were in the same phase of growth as the control, in the budding stage in the first study and in the blossoming and start of the fruit bearing stages in the other. Some delay in development of the control and test plants was due to insufficient light intensity, especially in the first study (2000 lux). The light intensity was made 4000 lux in the other study. Arabidopsis is a long day plant. With a 16 hour day and 10,000 lux light intensity, the ontogenesis of Arabidopsis is completed in 45-47 days.

/76*

/77

For electron microscope study, the root tips of the control and test plants (length 3 mm) were fixed under laboratory conditions with

[1]The Svetoblok-1 apparatus was prepared at the Institute of General Genetics, USSR Academy of Sciences.

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2.5% glutaraldehyde solution in 0.1 M cacodylate buffer at pH 7.2 for 12 hours, and postfixed with 1% OsO_4 solution for 3 hours at room temperature. The material was dehydrated according to the customary procedure in siccative concentration alcohols and propylene oxide and was embedded in epon-araldite. Sections were prepared in a LKB system ultramicrotome, contrasted with uranyl acetate and lead citrate, and they were studied in a JEM 100 B electron microscope.

The root caps of Arabidopsis, like other dicotyledonous plants [1], originate from a common germ layer with the epidermis (dermatocalyptrogen) and therefore its growth is really connected with that of the apical meristem of the root. In the central column or columella of the formed cap, the cells of the central statencheyme (statocytes) and peripheral secretory cells form. Between the meristem of the cap and the central statencheyme, there is an intermediate zone of cells which differentiate. The cells of the central statencheyme, as is characteristic of any type of cell in the majority of angiosperms, have large amyloplasts located in the distal ends of the cells and, according to the starch statolith hypothesis of Nemetz-Haberlandt [2], they perform the function of statolith. The number of root cap layers which are not considered meristem cells is 6-8. For a comparative analysis of the control and test material, caps were selected which were made up of the same number of cell layers, but at least 6.

As the study results showed, the columella cells of the caps of the test plants were more vacuolized than those of the controls. In the distal secretory cells of the cap, nearly complete lysis of the cytoplasm occurs, organelles are not found, and the cell locations are membranes and electron dense conglomerates. The cells of the central statenchyme, the protoplasts of which are preserved, have few amyloplasts. The latter, in contrast to those of the control cells, were distributed throughout the entire cytoplasm without any marked regularity. In the electron dense stroma of the plastids, circular membrane formations and small starch grains were frequently observed (see insert, a-d [not provided]). The round or oval nuclei, especially with diffuse chromatin and with one nucleolus as a rule, were closer

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to the proximal ends of the cells.

Cases were distinguished of partial lysis of the transverse membranes between the cells of the intermediate zone and the cells of the central statenchyme (see figure, e, f [not provided]). A portion of the cells of the meristem zone were rounder than the controls.

The data obtained confirm the facts we established [3], and they indicate that the change in topography of the amyloplasts and their ultrastructure in the cells of the central statenchyme of the root cap in weightlessness is regular for higher plants. Increased vacuolization of the cells of the central statenchyme, change in topography of the amyloplasts and lysis of the transverse cell membranes have been described in the literature [4] in Lepidium sativum (L.), in studies on compensation of the gravity vector by the slow clinostat /78
method (2 r/min) over a 20 hour period. While rearrangement of the ultrastructural organization of only the cells of the central statenchyme was observed in a short clinostat exposure, space flight conditions had a greater effect on the structural and functional organization of all cells of the root cap. According to the data of [5], ethylene strengthens the growth of plants under clinostat conditions. Ethylene decreases the level of metabolism of phospholipids, which results in a change in membrane permeability and the release of hydrolytic enzymes and, finally, to intensification of autolytic processes in the cytoplasm. In considering the similarity of the biological effects of clinostate conditions and weightlessness at the structural level, a similar mechanism of increased vacuolization of cells in weightlessness can be assumed.

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